FAUNAL DIVERSITY OF CLADOCERA (CRUSTACEA: BRANCHIOPODA) OF DEEPOR BEEL, ASSAM (NORTH-EAST INDIA) – A RAMSAR SITE

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Plankton samples collected from the Deepor beel, a Ramsar site, revealed 45 species of Cladocera belonging to 30 genera and 7 families, representing the highest biodiversity of these micro-crustaceans known till date from any individual aquatic ecosystem of the Indian subcontinent. The cladoceran taxocoenosis is characterized by the predominance of Chydoridae > Daphniidae, Cosmopolitan > Cosmotropical elements, general tropical character and occurrence of several interesting species. The richness (17-41, 29 ±6; 20-41, 32 ±6 species) exhibits multimodal and trimodal monthly patterns with peaks during winter and minima during early summer, and records 53.3-93.3 and 58.6-97.5% community similarities (*vide* Sorenson's index) at two sampling stations (I and II) respectively. Our results indicate lack of seasonal periodicity of occurrence of different species or families, show dominance of facultative planktonic littoral-periphytic elements and occurrence of fewer limnetic species. The cluster analysis exhibits higher similarities in composition of Cladocera during winter and autumn, while spring and summer communities show more qualitative differences. ANOVA registers significant differences in species richness between sampling stations as well as between months. The richness registers significant inverse relationship with water temperature and rainfall, and direct correlation with transparency, dissolved oxygen and hardness; while multiple regression indicates significantly higher cumulative influence of ten abiotic factors.

Key words: Ramsar site, Deepor beel, Cladocera, faunal diversity, distribution, temporal variations

INTRODUCTION

Taxonomic studies on Indian freshwater Cladocera were initiated by Baird (1860), subsequent publications deal with their α-taxonomy based on collections from scattered localities of India (Sharma and Michael 1987; Michael and Sharma 1988; Sharma 1991). The information on ecosystem diversity of these entomostracous crustaceans in various aquatic ecosystems, in general, and in the floodplain lakes and wetlands of India, in particular, is still scanty. This generalization especially holds true for the cladoceran fauna of north-eastern India wherein the only contribution on ecosystem diversity is restricted to the rice-field environs of Meghalaya (Sharma, in press). The observations are made presently on nature and composition of the cladoceran taxocoenosis of Deepor beel, temporal variations in species richness, community similarities, occurrence and distribution of interesting elements, and on influence of abiotic factors on their richness.

STUDY AREA

The present study was undertaken from November, 2004 to October, 2005 at Deepor beel (26° 03' 26" N; 90° 36' 39" E; area: 40 sq. km; altitude: 42 m above msl) located in Kamrup district of lower Assam (NE India). This perennial floodplain wetland and a Ramsar site is covered with a luxuriant growth of diverse aquatic macrophytes, namely *Hydrilla verticellata*, *Najas indica*, *Euryale ferox*, *Vallisneria spiralis*, *Utricularia flexuosa*, *Trapa bispinosa*, *Eichhornia crassipes*, *Monochoria hastaefolia*, *Xanthium straumarium*, *Ipomea fistulosa*, *Croton borplandianum*, *Hygroryza aristata*, *Polygonum hydropiper* and *Limnophila* sp.

METHODOLOGY

Water samples collected monthly from two sampling stations (I and II) were analyzed for various abiotic factors. Water temperature, specific conductivity and pH were recorded using field probes, and transparency was noted with a Secchi disc. Dissolved oxygen was estimated using modified Winkler's method and other chemical parameters were analyzed following APHA (1992).

Qualitative plankton samples were obtained from the two sampling stations by towing a nylobolt plankton net (No. 25), and were preserved in 5% formalin. Various species and their disarticulated appendages were mounted in Polyvinyl alcohol-lectophenol mixture. The head pores and their arrangements were studied following Megard (1965). The cladoceran species were identified from Smirnov (1971, 1976, 1992, 1996), Smirnov and Timms (1983), Michael and Sharma (1988), Korovchinsky (1992), Sharma and Sharma (1999), Orlova-Bienkowskaja (2001) and Korinek (2002).

Percentage similarities between monthly cladoceran communities were calculated *vide* Sorensen index and were analyzed by the hierarchical cluster analysis. Ecological relationships were computed *vide* simple correlation coefficients (r_1 and r_2) and multiple regression (R_1^2 and R_2^2) at stations I and II individually and significance of temporal variations was ascertained *vide* ANOVA.

SYSTEMATIC LIST OF THE EXAMINED TAXA

Super-class: Crustacea
Class: Branchiopoda
Super-order: Cladocera *s. str.*
Order: **Ctenopoda**
Family: **Sididae**

1 *Diaphanosoma excisum* Sars, 1885
2. *D. sarsi* Richard, 1895
3. *Pseudosida bidentata* Herrick, 1884
4. *Sida crystallina* (O.F. Müller, 1776)

Order: **Anomopoda**
Family: **Daphniidae**

5. *Ceriodaphnia cornuta* Sars, 1885
6. *C. reticulata* (Jurine, 1820)
7. *Scapholeberis kingi* Sars, 1903
8. *Simocephalus acutirostratus* (King, 1853)
9. *S. serrulatus* (Koch, 1841)
10. *S. vetulus* (O.F. Müller, 1776)

Family: **Bosminidae**

11. *Bosmina longirostris* (O.F. Müller, 1776)
12. *Bosminopsis deitersi* Richard, 1895

Family: **Moinidae**

13. *Moina micrura* Kurz, 1874
14. *Moinodaphnia macleayi* (King, 1853)

Family: **Macrothricidae**

15. *Macrothrix laticornis* (Fischer, 1857)
16. *M. triserialis* (Brady, 1886)
17. *Grimaldina brazzai* Richard, 1892

Family: **Ilyocryptidae**

18. *Ilyocryptus spinifer* Herrick, 1882

Family: **Chydoridae**
Subfamily: **Chydorinae**

19. *Alonella excisa* (Fischer, 1854)
20. *Chydorus faviformis* Birge, 1893
21. *C. pubescens* Sars, 1901
22. *C. sphaericus* (O.F. Müller, 1776)
23. *C. reticulatus* Daday, 1898
24. *Dadaya macrops* (Daday, 1898)
25. *Disperalona caudata* Smirnov, 1996
26. *Dunhevedia serrata* Daday, 1898
27. *Ephemeroporus barroisi* Richard, 1894
28. *Picripleuroxus similis* (Vavra, 1900)

Subfamily: **Aloninae**

29. *Acroperus harpae* (Baird, 1894)
30. *Alona affinis* (Leydig, 1860)
31. *A. intermedia* Sars, 1862
32. *Alona costata* Sars, 1862
33. *A. globulosa* (Daday, 1898)
34. *A. guttata* Sars, 1862
35. *A. quadrangularis* (O.F. Müller, 1776)
36. *A. rectangula* Sars, 1862
37. *Euryalona orientalis* (Daday, 1898)
38. *Camptocercus rectirostris* Schoedler, 1862
39. *C. uncinatus* Smirnov 1971
40. *Graptoleberis testudinaria* (Fischer, 1854)
41. *Karualona karua* (King, 1853)
42. *Kurzia longirostris* (Daday, 1898)
43. *Leydigia acanthocercoides* (Fischer, 1854)
44. *Leydigiopsis curvirostris* Sars, 1901
45. *Oxyurella singalensis* (Daday, 1898)

RESULTS AND DISCUSSION

Water samples collected from Deepor beel show low specific conductivity and are thus characterized (Table 1) by low ionic concentrations; this feature warrants the inclusion of this Ramsar site under 'Class I' category *vide* Talling and Talling (1965). Mean water temperature affirms tropical range concurrent with its geographical location. The circum-neutral and marginally hard waters of this wetland show moderate dissolved oxygen, low free CO_2 and low concentration of micro-nutrients. Chloride and BOD_5 values reflect some possible impact of human activity. In general, the ranges of abiotic factors broadly concur at the two sampling stations (I and II) and also agree with earlier results of Sharma and Hussain (1999) and Sharma (2005).

Plankton samples examined from the Deepor beel reveal 45 species of Cladocera belonging to 30 genera and 7 families; the richest biodiversity known till date from any individual floodplain lake or aquatic ecosystem of the Indian subcontinent. The cladoceran fauna is rich and diverse both in species, and genera and families. The former aspect assumes special importance in view of a conservative estimate of occurrence of up to 60-65 Cladocera species in tropical and subtropical environs of India (Sharma and Michael 1987;

Table 1: Abiotic factors of Deepor beel

Factors	Station I	Station II
Rainfall (mm)	204.5 ± 160.4	204.5 ± 160.4
Water temperature (°C)	27.2 ± 4.6	27.4 ± 5.1
pH	6.89 ± 0.18	6.93 ± 0.21
Transparency (cm)	51.9 ± 26.2	52.7 ± 25.3
Specific Conductivity (µS/cm)	99.2 ± 13.2	96.8 ± 15.5
Dissolved oxygen (mg/l)	6.7 ± 1.6	7.0 ± 1.1
Free CO_2 (mg/l)	7.2 ± 2.1	6.8 ± 1.9
Alkalinity (mg/l)	66.3 ± 12.1	68.9 ± 10.3
Hardness (mg/l)	62.1 ± 9.9	61.2 ± 12.3
Calcium (mg/l)	20.1± 2.2	22.1± 1.8
Magnesium (mg/l)	4.0 ± 0.7	4.2 ± 0.9
Chloride (mg/l)	34.6 ± 5.2	35.1 ± 5.0
Phosphate (mg/l)	0.18 ± 0.07	0.19 ± 0.10
Sulphate (mg/l)	10.2 ± 3.2	9.9 ± 3.4
Nitrate (mg/l)	0.72 ± 0.12	0.74 ± 0.14
Silicate (mg/l)	3.02 ± 1.02	3.10 ± 1.27
BOD_5 (mg/l)	3.11 ± 0059	3.21 ± 0.46
Dissolved Organic Matter (mg/l)	3.84 ± 0.80	3.90 ± 0.64
Total dissolved Solids (mg/l)	2.37 ± 0.29	2.57 ± 0.30

Sharma 1991). The present results in general reflect environmental heterogeneity and micro-habitat diversity of this important wetland of north-east India; this generalization re-affirms our earlier remarks (Sharma and Sharma 2005) based on the biodiversity of Rotifera of Deepor beel.

The Cladocera richness noticed in our observations presents a distinct contrast to the reports of only 11 species from two floodplain lakes (Khan 1987) of Kashmir; 9 species from 65 wetlands of 24-Parganas district (Nandi *et al.* 1993) of West Bengal; one species (Baruah *et al.* 1993), 4 species (Sinha *et al.* 1994) and 12 species (Sanjer and Sharma 1995) from the floodplains of Bihar; 14 species from 37 floodplain lakes (Sarma 2000) of Assam, 3 species from Mori beel (Goswami and Goswami 2001) from Assam; and 36 species from 20 wetlands from the floodplains of south-eastern West Bengal (Khan 2003). The notably lower richness in various mentioned works may be attributed to incomplete species inventories, due to lack of taxonomic expertise of several earlier workers, coupled with lack of extensive sampling of the cladoceran communities. The faunal diversity of these micro-crustaceans in Ramsar sites of India, distinctly exceeds 12 species, including certain doubtful species, recorded from Loktak (Shyamananda Singh 1991), an important floodplain lake of Manipur. The present report is also higher than the 30 species examined from 30 wetlands of Keoladeo National Park (Venkataraman 1992).

Leydigiopsis curvirostris and *Disperalona caudata* are two globally interesting species documented from Deepor beel. The former is known only from Brazil and is now reported as a new record from the Oriental region (Sharma and Sharma 2007). Further, we initially believed it to be rare and restricted to Deepor beel, but it was observed recently in our samples collected from certain beels of upper Assam and Cachar district. *D. caudata* is a new addition to the Indian subcontinent and is so far recorded only from Thailand and Australia; this chydorid is, hence, designated as an Australasian element (Sharma and Sharma *loc cit.*), and shows an interesting affinity between the Cladoceran fauna of north-eastern India, Southeast Asia and Australia. Our report of the occurrence of the two species in India may represent an example of their introduction by man and thus deserves further attention. This generalization re-affirms remarks of Dumont (1997) regarding emphasis on human introductions of several cladoceran species in different parts of the globe.

Camptocercus uncinatus is a biogeographically interesting recent addition to the Indian Cladocera (Sharma 2008); the present study represents its second record from this country. Our observations indicate possible wider distribution of this chydorid and call for the need of re-examination of all earlier reports of an allied species, *C. australis* from India and elsewhere. *Grimaldina brazzai* is yet another interesting addition to the cladoceran fauna of north-eastern India; this circumtropical member of the Macrothricidae is known so far from Rajasthan and West Bengal. In addition, twenty-four species are new records from Assam. Species such as *Ceriodaphnia reticulata*, *Chydorus faviformis*, *C. pubescens*, *C. reticulatus*, *Dadaya macrops*, *Graptoleberis testudinaria* and *Kurzia longirostris* comprise examples of a regional distributional interest.

The cladoceran fauna of Deepor beel depicts a general tropical character with a greater qualitative richness of Cosmopolitan > Cosmotropical species and presence of several Circumtropical and Pantropical species. These salient features are endorsed by the occurrence of a typical Circumtropical genera namely *Dadaya* and *Grimaldina*, the Pantropical *Ephemeroporus* and the Tropicopolitan *Moinodaphnia*; though a number of the documented genera are known for their cosmopolitan or worldwide distribution (Dumont and Negrea 2002).

The examined collections are characterized by qualitative predominance of the littoral-periphytonic species which, in turn, is attributed to shallow nature of this wetland together with the growth of several aquatic macrophytes. The notable among these are the members of the Chydoridae, Macrothricidae, Sididae and Ilyocryptidae. On the other hand, the cladoceran communities include fewer limnetic taxa belonging to the Daphniidae, Bosminidae and Moinidae. The sporadic occurrence of limnetic *Daphnia lumholtzi* at the two sampling stations of Deepor beel during winter season merits special interest for further investigations. Further, it may be

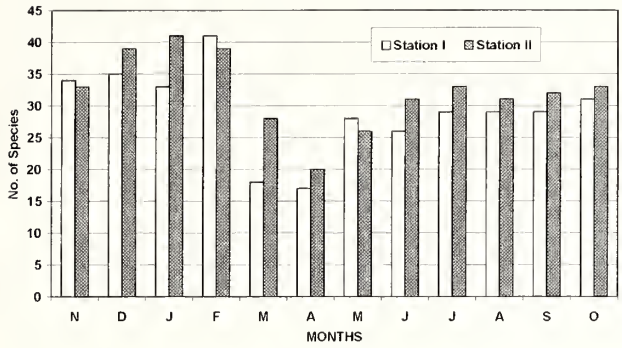

Fig. 1: Cladocera richness

noted that *D. lumholtzi* shows very restricted occurrence and distribution in aquatic environs of north-eastern India.

In general, the Cladocera contribute significantly to richness of zooplankton ($r_1 = 0.921$, $r_2 = 0.952$) and micro-crustacean ($r_1 = 0.992$, $r_2 = 0.995$) communities of the Deepor beel. The broadly comparable total number of species observed at station I (45 species) and II (43 species) may be attributed to broadly identical macrophyte associations at the sampled sites. The monthly cladoceran richness varies between 17-41 (29 ±6) and 20-41 (32 ±6) species, and exhibits (Fig. 1) multimodal and trimodal patterns of temporal variations at two sampling stations respectively. The peak richness is noticed during winter and dips are observed during summer; the present results, however, exhibit lack of seasonal periodicity of different species or families. ANOVA registers significant temporal variations in the species richness between sampling stations ($F_{1, 11} = 9.992$, $p < 0.005$) and between months ($F_{11, 11} = 11.240$, $p < 0.005$).

The Cladocera richness exhibits significant inverse correlation with water temperature ($r_1 = -0.776$, $r_2 = -0.803$) and rainfall ($r_1 = -0.768$, $r_2 = -0.720$) and direct relationship with transparency ($r_1 = 0.591$, $r_2 = 0.609$), dissolved oxygen ($r_1 = 0.782$, $r_2 = 0.683$) and hardness ($r_1 = 0.552$, $r_2 = 0.523$). Besides, it records direct correlation with specific conductivity only at station II ($r_2 = 0.622$). Multiple regression indicates notably higher cumulative influence of ten abiotic factors,

Table 2: Percentage similarities (Sorenson's index) between Cladoceran communities (Station I)

Months	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
November	-	88.8	88.2	88.0	61.5	62.7	85.2	76.7	88.9	85.7	79.4	86.1
December		-	91.4	93.3	59.2	60.4	82.5	74.2	86.1	83.1	83.1	80.6
January			-	88.0	61.5	58.8	78.7	73.0	79.4	82.5	79.4	83.1
February				-	57.6	58.6	76.5	77.6	82.9	77.1	82.0	83.3
March					-	74.3	53.3	77.3	68.1	59.6	63.8	65.3
April						-	59.1	69.8	69.6	65.2	65.2	58.3
May							-	64.1	82.1	89.3	78.6	79.3
June								-	72.7	72.7	69.1	77.2
July									-	86.2	79.3	90.0
August										-	79.3	80.0
September											-	76.7
October												-

Table 3: Percentage similarities (Sorenson's index) between Cladoceran communities (Station II)

Months	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
November	-	88.9	89.2	91.7	78.7	64.1	78.0	78.1	81.8	81.8	76.9	84.8
December		-	95.0	94.9	77.0	61.0	76.9	82.8	86.1	85.7	87.3	91.7
January			-	97.5	81.1	59.0	77.6	83.3	86.5	83.3	84.9	83.8
February				-	77.6	61.0	76.9	85.7	93.3	82.9	84.5	88.9
March					-	58.6	66.9	74.6	72.1	74.6	76.7	78.7
April						-	78.3	66.7	64.1	66.7	65.4	64.1
May							-	77.2	77.2	80.7	75.9	74.6
June								-	78.1	83.9	79.4	78.1
July									-	87.5	83.1	84.8
August										-	82.5	78.1
September											-	86.1
October												-

namely water, temperature, rainfall, pH, transparency, specific conductivity, dissolved oxygen, alkalinity, hardness, phosphate and nitrate on their monthly richness at the two sampling stations ($R_1^2 = 0.9803$, $R_2^2 = 0.9922$). The step-wise regression, however, records significance of hardness, conductivity, pH and transparency at station I and of only hardness and pH at station II.

Chydoridae, the most diverse family of Cladocera, forms a distinctly dominant qualitative component at the Deepor beel with occurrence of 27 species belonging to 17 genera and contributes significantly to the richness of these micro-crustaceans at the two sampling stations ($r_1 = 0.726$, $r_2 = 0.779$). The Chydorid richness varies between 9-24 (17±4) and 12-22 (19±3) species at the two stations respectively and registers significant temporal variations between stations ($F_{1, 11} = 7.693$, $p < 0.01$) as well as months ($F_{11, 11} = 8.705$, $p < 0.005$). Further, this family follows multimodal and trimodal patterns (Fig. 2) of monthly richness identical to that of the Cladocera and shows lack of any seasonal periodicity. The Chydoridae indicate significant inverse correlation with water temperature ($r_1 = -0.637$, $r_2 = -0.759$) and rainfall ($r_1 = -0.638$, $r_2 = -0.661$), and direct relationship with transparency ($r_1 = 0.605$, $r_2 = 0.673$), dissolved oxygen ($r_1 = 0.652$, $r_2 = 0.777$) and hardness ($r_1 = 0.548$, $r_2 = 0.609$). In addition, the Chydorids record significant direct correlation with specific conductivity ($r_2 = 0.615$) and alkalinity ($r_2 = 0.646$) only at station II.

The cladoceran communities indicate (Tables 2, 3) similarities (*vide* Sorenson's index) ranging between 53.3-93.3% (station I) and 58.6-97.5% (station II). Our results show values between >70-90% in majority of instances (65.1% and 75.8 %) included in the two similarity matrices respectively and, therefore, exhibit lesser monthly variations in their species composition. Further, the samples collected during winter (December *vs.* February at station I, January *vs.* February at station II) record peak similarities while

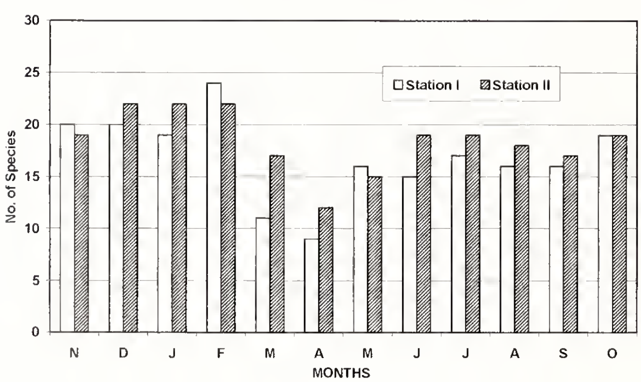

Fig. 2: Chydoridae richness

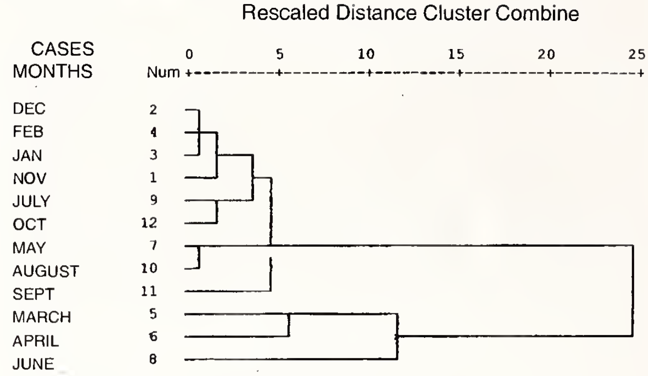

Fig. 3: Dendrogram showing Hierarchical Cluster Analysis between Cladoceran communities (Station I)

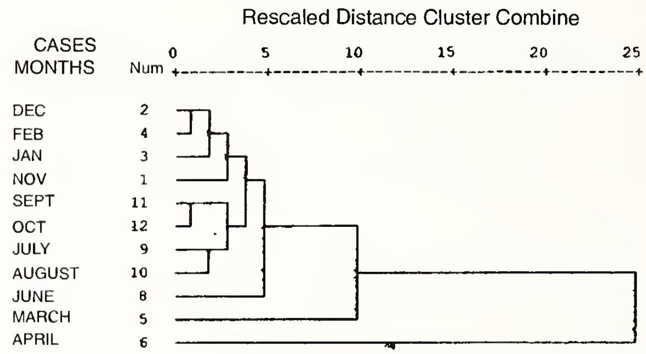

Fig. 4: Dendrogram showing Hierarchical Cluster Analysis between Cladoceran communities (Station II)

minima are recorded during spring and early summer (March *vs.* May at Station I, March *vs.* April at station II). The cluster analysis exhibits higher closeness in composition of Cladocera of the Deepor beel during winter and autumn at the two sampling sites (Figs 3, 4), while spring and summer communities show more qualitative differences. These features may be attributed to a higher richness and common occurrence of several species particularly during November-February as compared with notably lower number of species, as well as differences in their composition during March-May / June.

To conclude, the Cladocera communities of Deepor beel are characterized by rich and diverse nature, qualitative predominance of the facultative planktonic and the littoral-periphytonic species, and exhibit lack of seasonal periodicity of different species or families. The present results indicate influence of only certain individual abiotic factors on the richness while ten abiotic factors register higher commutative influence.

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